EFFECT OF INDIUM ADDITION ON MICROSTRUCTURE, WETTABILITY, SHEAR STRENGTH AND CREEP BEHAVIOR OF SN100C SOLDER

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by

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LIST OF EQUATION

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Material
Ag	Argentum (silver)
Al	Aluminium
Au	Gold
BGA	Ball Grid Array
Bi	Bismuth
Cd	Cadmium
Ce	Cerium
Co	Cobalt
cm	Centimeter
CNC	Computer Numerical Control
CSPs	Chip scale packages
Cu	Copper
DIP	Dual In Line Package
DSC	Differential Scanning Calorimetry
EDX	Electron Dispersive X-Ray Spectroscopy
Fe	Iron
g	Gram (weight)
Ga	Gallium
Ge	Germanium
IC	Integrated circuit

IMC	Intermetallic Compound
In	Indium
kN	Kilo Newton
mg	Milligram
min	Minute (time)
mm	Milimeter (length)
mol	Molecular
MPa	Mega Pascal
Ni	Nickel
µm	Micrometer
OM	Optical Microscopy
OSP	Organic solderability protection
P	Phosphorus
Pb	Plumbum
Pd	Palladium
Pt	Platinum
PTH	Pin Through Hole
PCB	Printed Circuit Board
PGA	Pin Grid Array
RA	Activated rosin
RoHS	Restriction of Hazardous Substance
S	Sulphur
SAC	Sn-Ag-Cu

SAL	Sebatian Antara Logam
Sb	Antimony
Sec	Second
SEM	Scanning Electron Microscopy
SMT	Surface Mount Technology
SN100C	Sn-0.7Cu-0.05Ni-Ge
SN100C-0.5In	Sn-0.7Cu-0.05Ni-0.5In
SN100C-1In	Sn-0.7Cu-0.05Ni-1In
SN100C-1.5In	Sn-0.7Cu-0.05Ni-1.5In
SN100C-2In	Sn-0.7Cu-0.05Ni-2In
Sn	Stanum (Tin)
SnCu	Copper-tin
SnIn	Indium-tin
SnPb	Lead-tin
SnZn	Zinc-tin
SnCuNi	Tin-Copper-Nickel
SnCuIn	Tin-Copper-Indium
SnAgCu	Tin-Silver-Copper
SnCuBi	Tin-Copper-Bismuth
XRF	X-Ray Fluorescent
Zn	Zinc

LIST OF SYMBOLS

A	Area
β-Sn	Sn-rich phase
°C	Celsius
°C/min	Degree Celsius per minute
d	IMC thickness after aging
d_o	Initial IMC thickness
D	Diffusion coefficient
D_o	Intrinsic Diffusivity
ε	Creep strain
έ	Creep strain rate
ε0	Instantaneous Creep Strain
εpc	Primary Creep Strain
εp&s	Primary and Steady State Creep Strain
$\dot{\varepsilon}$ss	Steady State Creep Strain Rate
°F	Fahrenheit (temperature)
F	Wetting force
F_b	Buoyancy force
F_e	End force
F_{max}	Maximum wetting force
F_w	Withdrawal force
G	Shear Modulus

J	Joule
m	meter
μ	micron
N	Newton
n	Creep Stress Exponent
η	Homologous Temperature
ρ	Density of the Solder
Q	Activation energy
R	Gas constant
S_b	Ratio of wetting force just before withdrawal to the wetting force during complete wetting
t_1	Wetting time
T	Temperature
T_c	Crystallization temperature
T_m	Melting temperature
τ	Shear Stress
θ	Wetting angle
θ_c	Contact Angle
σ	Stress
γ	Surface tension of solder
γsg	Surface tension between solid and gas
γsl	Surface tension between solid and liquid
γlg	Surface tension between liquid and gas

^{o}C	Degree Celsius
%	Percentage
wt%	Weight percent

KESAN PENAMBAHAN INDIUM TERHADAP MIKROSTRUKTUR, KEBOLEHBASAHAN, KEKUATAN RICIH DAN KELAKUAN RAYAPAN PATERI SN100C

ABSTRAK

Disebabkan kebimbangan toksik plumbum terhadap alam sekitar, penggunaan pateri tanpa plumbum telah digunakan secara meluas dalam industri pembungkusan elektronik. Dalam mencari alternatif menggantikan pateri plumbum, pateri bebas plumbum haruslah mempunyai takat lebur yang hampir sama dengan pateri plumbum (183°C), serta mempunyai kebolehbasahan, sifat fizikal dan mekanikal yang baik. Diantara pateri bebas plumbum, aloi Sn-Cu pateri menunjukkan kesesuaian yang baik untuk menggantikan pateri plumbum. Walau bagaimanapun, pateri Sn-Cu pateri mempunyai takat lebur dan sudut basahan yang tinggi berbanding dengan pateri plumbum. Takat lebur yang tinggi akan menyebabkan suhu pematerian tinggi yang membawa risiko lebih tinggi terhadap komponen dan substrat yang sensitif dan tidak dapat menahan suhu tinggi. Tujuan projek ini adalah untuk mengkaji tingkah laku haba, mikrostruktur, kebolehbasahan, sifat mekanikal dan kelakuan rayapan SN100C pateri (Sn-0.7Cu-0.05Ni-0.01Ge) dengan penambahan indium (0.5,1.0,1.5 dan 2.0wt%). Ciri-ciri, mikrostruktur, sifat fizikal dan mekanikal dan kelakuan rayapan pateri SN100C telah dikaji menggunakan mikroskop optik, mikroskop imbasan elektron, kalorimeter imbasan perbezaan, dan mesin Instron. Dengan penambahan indium 0wt% ke 2.0wt%, suhu lebur menurun dari 229.64°C ke 225.40°C. Selain itu, kebolehbasahan turut meningkat dengan peningkatan kuantiti indium. Mikrostruktur pukal aloi pateri menunjukan saiz butir aloi menurun dan dendrit β-Sn menjadi lebih halus dengan pertambahan indium. Juga diperhatikan bahawa SAL $(Cu, Ni)_6Sn_5$ dan

Sn-Cu-Ni-In telah terbentuk dengan pertambahan indium dari 0.5wt% hingga 2.0wt% Bersama dengan Cu_6Sn_5. Penambahan indium sebanyak 2.0wt% telah membawa kepada peningkatan kekuatan mekanikal. Merujuk kepada sifat rayapan aloi dengan indium 2.0wt% menunjukkan rintangan rayap paling tinggi yang disebabkan oleh penghalusan mikrostruktur. Penghalusan butir dan pembentukan sal di dalam aloi pateri mengakibatkan halangan kepada pergerakkan kehelan. Berdasarkan eksponent tegasan dan tenaga pengaktifan rayapan yang diperolehi, telah dicadangkan bahawa mekanisme ubah bentuk yang dominan bagi pateri SN100C ditambah indium ialah pendakian kehelan pada julat suhu yang dikaji. Penambahan 2.0 wt% indium diperhatikan dapat menggalakkan penghalusan butir dalam pateri SN100C dengan peningkatan pada sifat mekanikal, kebolehbasahan yang lebih baik dan rintangan rayapan yang lebih baik.

EFFECT OF INDIUM ADDITION ON MICROSTRUCTURE, WETTABILITY, SHEAR STRENGTH AND CREEP BEHAVIOUR OF SN100C SOLDER

ABSTRACT

Due to environmental concern of lead toxicity, the use of lead-free solder has been widely used in electronic packing industries. In finding alternative of lead-free solder to replace the current lead solder, the lead-free solder should have a melting point close to lead solder (183°C), has good wettability, as well as excellent physical and mechanical properties. Among lead-free solders, Sn-Cu alloy is the most compatible to replace the lead solder. However, Sn-Cu solder has a high melting point and wetting angle compared to lead solder. The high melting point caused high soldering temperature, which might expose the sensitive components and substrate to a risk since it cannot withstand high temperature. The aim of this project is to evaluate thermal behaviour, microstructure, wettability, mechanical properties and creep behaviour of SN100C solder (Sn-0.7Cu-0.05Ni-0.01Ge) with addition of indium. The microstructure characteristics, physical and mechanical properties, and creep behaviour of SN100C solder were investigated using optical microscope (OM), scanning electron microscope, differential scanning calorimetry (DSC), and Instron machine. With indium addition from 0wt% to 2.0wt%, the melting temperature was reduced from 229.64 °C to 225.40°C. The wettability of solder alloys improved with increasing amount of indium. Bulk microstructure of solder alloys showed that the grain size of solder decreased, and β-Sn grain became more refined with increasing amount of indium added. It is also observed that $(Cu, Ni)_6Sn_5$ and Sn-Cu-Ni-In IMC were formed with indium from 0.5 wt% to 2.0 wt.% alongside the Cu_6Sn_5. The addition

of 2.0wt% of indium also led to an improvement of shear strength. In term of creep properties, the alloy with 2.0wt% indium gave the highest creep resistance due to the refinement of microstructure. The refinement and formation of IMCs in the solder alloys can result in impeding the dislocation movement. According to the obtained stress exponent and activation energies, it is proposed that the dominant deformation mechanism in In-added SN100C solder is dislocation climb over the temperature range investigated. The indium addition at 2.0wt% was observed to induce grain refinement of SN100C solder with higher mechanical properties, better wettability behaviour and improved creep resistance.

CHAPTER 1
INTRODUCTION

1.1 Research Background

Tin-lead (Sn-Pb) solders have been widely used in electronic industry due to its combining advantages, such as low melting temperature, economically affordable and excellent wettability. Despite all these advantages, a switch to Pb-free solders to replace the toxic Pb-based solder in the packaging process of electronic device and components are still occuring rapidly. The toxicity of lead has been a focus of many discussion since the 1930s. Various published researches revealed that lead is hazardous, not only to the enviroments, but also to human health (Cory-slechta *et al*., 1983, Davies *et al*., 1976, Wassink, 1989) . Driven by these concerns and international legislation, electronic manufacturing companies and researchers have since concentrating their efforts in fabricating lead-free solder to replace the Sn-Pb solder. Indeed, many research groups have been focusing on developing new Pb-free solders (El-Daly *et al*., 2011, Keller *et al*., 2011). The new composition solder alloy must comply to these requirements such as; economically affordable material, good wettability, suitable melting temperature, excellent mechanical and electrical properties, high corrosion resistence and non-toxic for human health and enviroment (Gain *et al*., 2010).

The solder should be at least comparable to Sn-Pb solder or better. Considering all of the above criteria, thus far, there are only a handful of lead-free solder alternatives that could be appraised. For binary alloys, Sn-Bi, Sn-Cu, and Sn-Ag appear to be the choice. For ternary and quaternary lead-free alloy alternatives, there are Sn-Bi-Ag, Sn-Ag-In, Sn-Ag-Cu, Sn-Bi-Ag-Cu, and Sn-Ag-Sb-Bi (Zhang, 2010). Numerous investigations by consortia, industry alliances, and individual companies